THE STATE OF PLAY
US SPACE SYSTEMS COMPETITIVENESS

PRICES, PRODUCTIVITY, AND OTHER MEASURES OF LAUNCHERS & SPACECRAFT

EDGAR ZAPATA

COMMERCIAL SPACE TELECON MAY 19, 2021

DATA AS OF MAY 18, 2021 ATLAS V LAUNCH

Edgar Zapata

- NASA Kennedy Space Center – retired 32+ years
- About me, publications, more
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DATA + CONTEXT

Data

- Cost data from public prime contract awards, *govtribe.com*, award announcements and other public sources
  - Only part of the total cost to NASA, DoD, government (closer to "price")
- Cost data from public NASA budget documents, congressional records and other public sources
  - Other public data for personnel/government and other program/project related procurement costs
  - With prior, gets near to "total cost"
- Flight rate, payload, and other public data
  - The benefit across time, the cumulative benefit produced for that price/cost, long term

DATA + CONTEXT

- COST DATA FROM PUBLIC PRIME CONTRACT AWARDS, *GOVTRIBE.COM*, AWARD ANNOUNCEMENTS AND OTHER PUBLIC SOURCES
  - ONLY PART OF THE TOTAL COST TO NASA, DOD, GOVERNMENT (CLOSER TO "PRICE")
- COST DATA FROM PUBLIC NASA BUDGET DOCUMENTS, CONGRESSIONAL RECORDS AND OTHER PUBLIC SOURCES
  - OTHER PUBLIC DATA FOR PERSONNEL/GOVERNMENT AND OTHER PROGRAM/PROJECT RELATED PROCUREMENT COSTS
  - WITH PRIOR, GETS NEAR TO "TOTAL COST"
- FLIGHT RATE, PAYLOAD, AND OTHER PUBLIC DATA
  - THE BENEFIT ACROSS TIME, THE CUMULATIVE BENEFIT PRODUCED FOR THAT PRICE/COST, LONG TERM

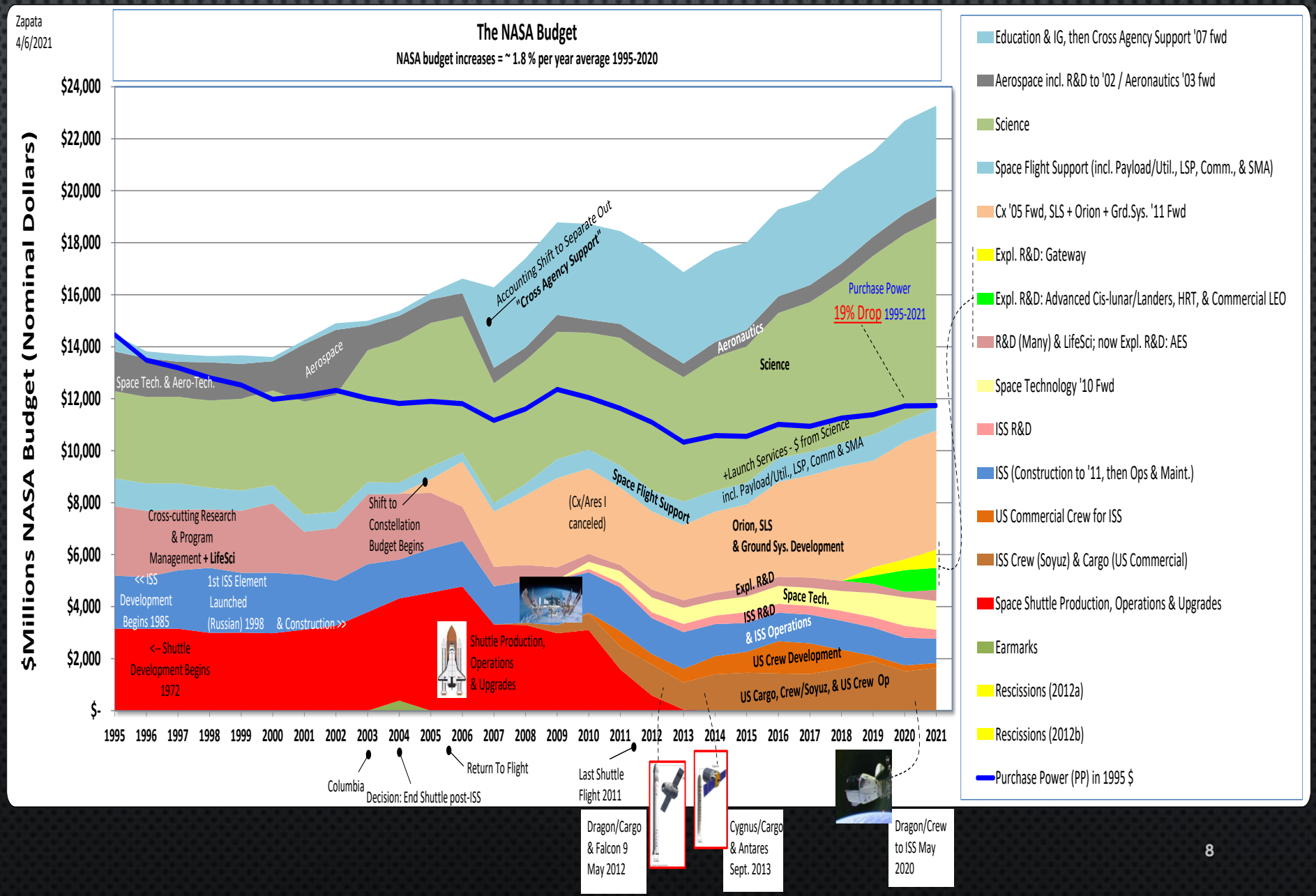
Context

- Expertise - interpret, organize, *distill*
- Favor fresh, recent data
- Consistency - adjust for apples-to-apples
  - Capability -same orbit
  - Dollars -nominal or inflation adjusted
  - Costs
    - Prime only or all procurement or total (*all different*)
    - Non-recurring, development, up-front
    - Recurring, operations, production, flights, missions, units
- Minimally process data
  - Splits between partners, elements, launch, spacecraft

NASA BUDGET

NASA BUDGET

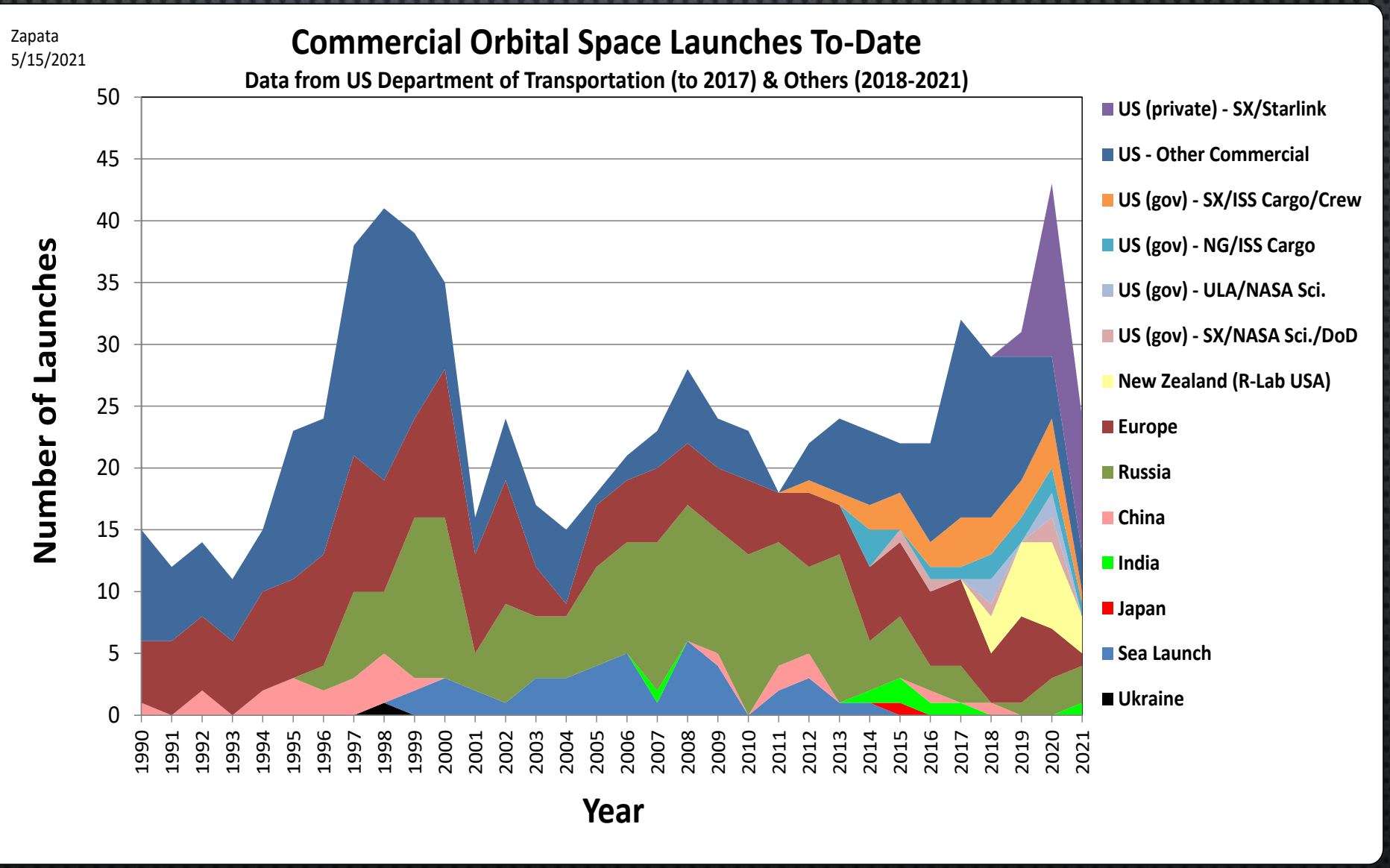
Purchase Power Drop 1995 to 2021 = 19%



LAUNCH

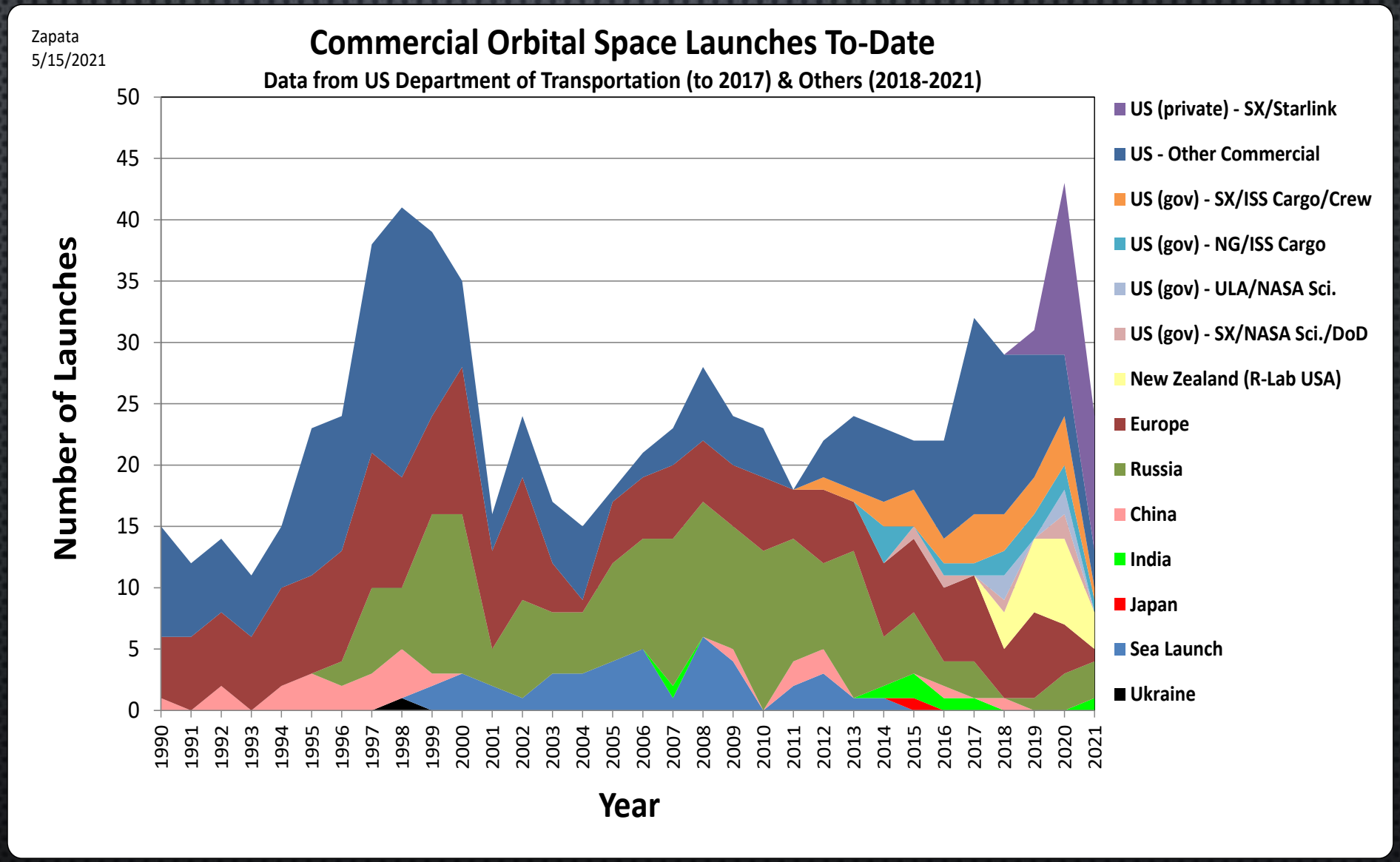
COMPETITIVENESS

- The DOT defines a commercial launch as a "*launch that is internationally competed (i.e., available in principle to international launch providers) or whose primary payload is commercial in nature*"; also FAA licensed launches. So interpreting, Starlink is "commercial in nature" and included here. Cargo and crew to the ISS, and NASA science missions are competed and awarded on commercial terms as a service and licensed by the FAA, even if only competed nationally, so also included here.
- Pending distinguishing which specific DOD missions after 2017 are "competed" vs. previous block-buys with only a single provider (ULA). See "DOD NSSL (was EELV)" ahead.

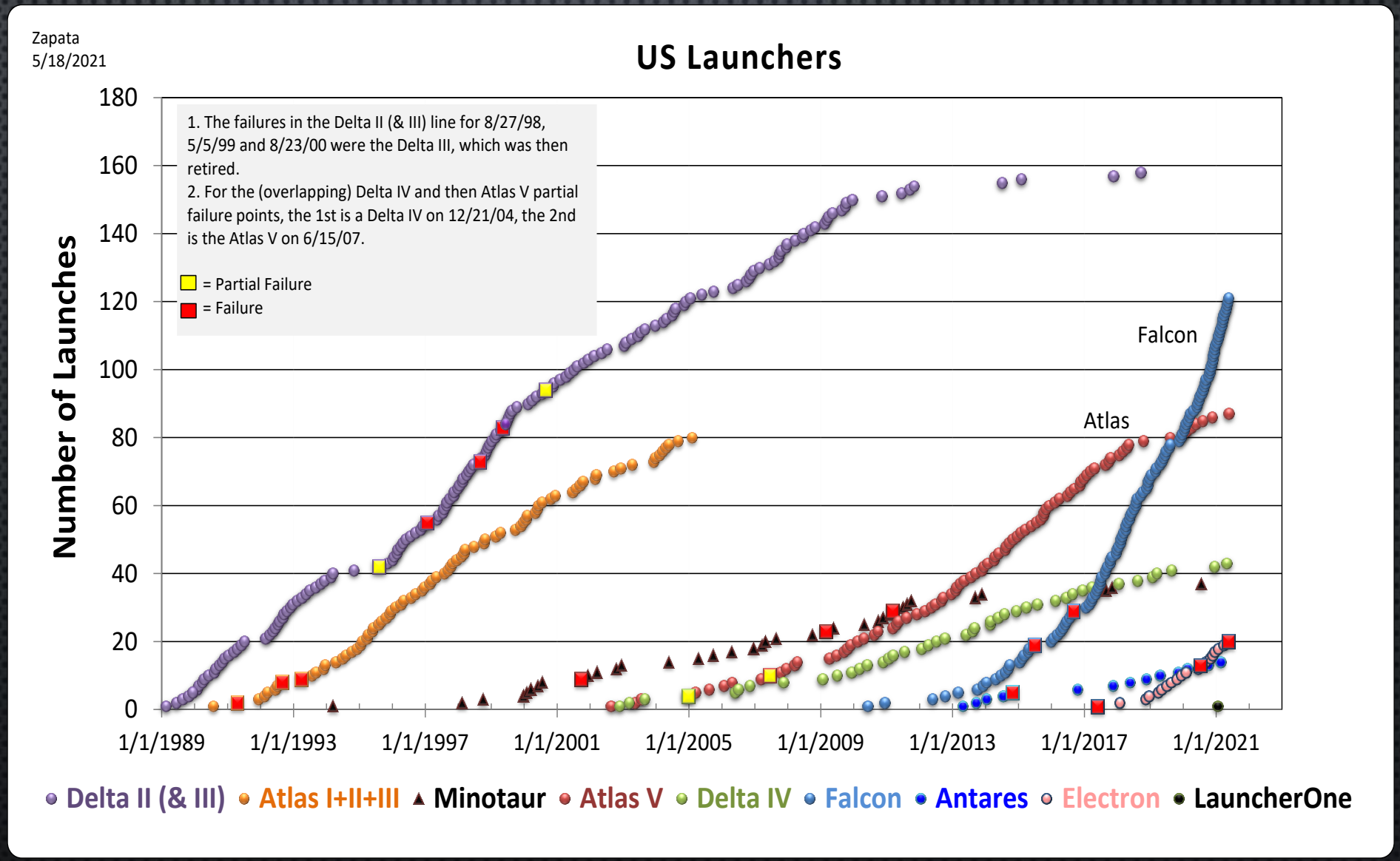


COMPETITIVENESS

MARKET ELASTICITY?

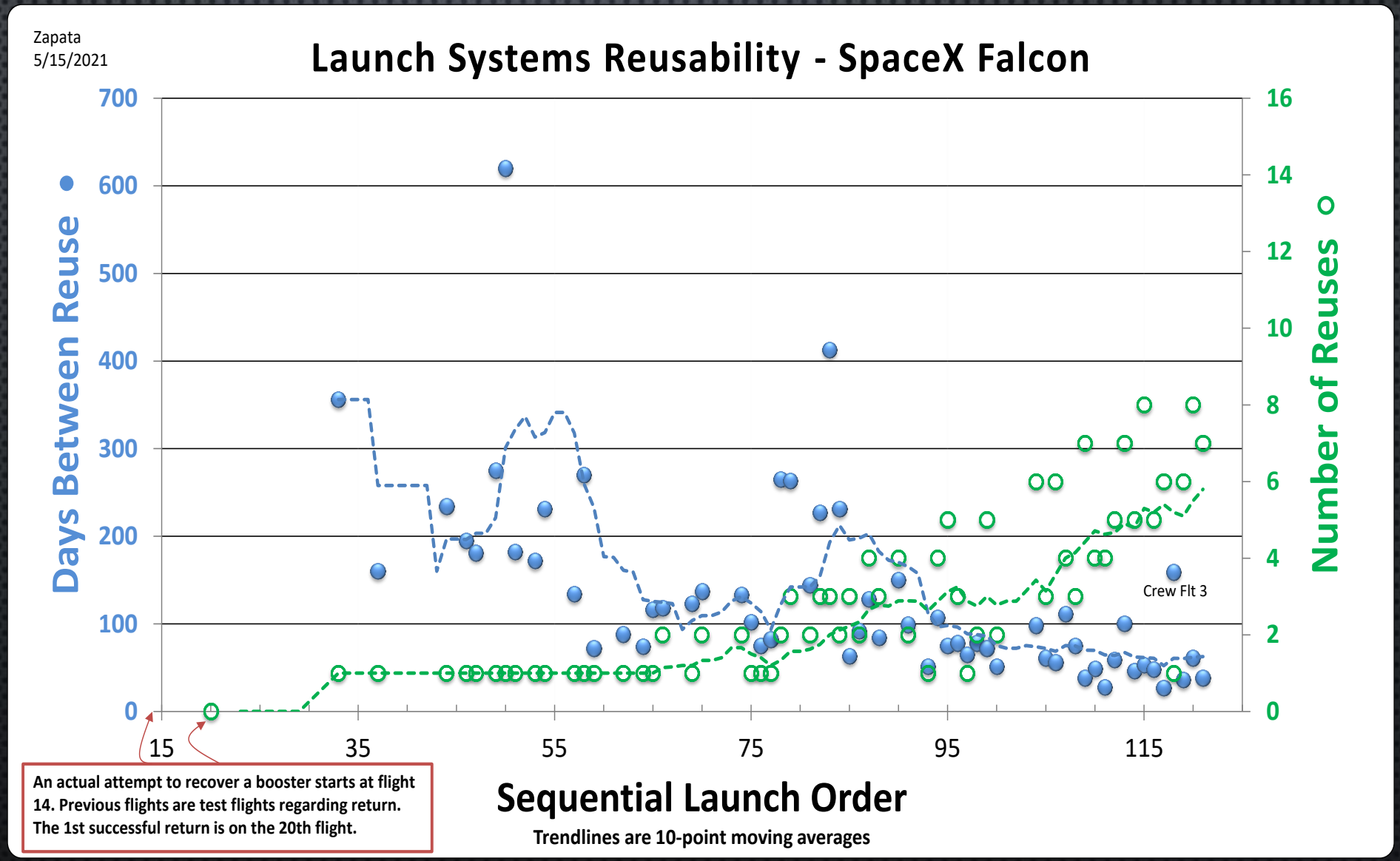


GROWTH PRODUCTIVITY



SUSTAINABILITY

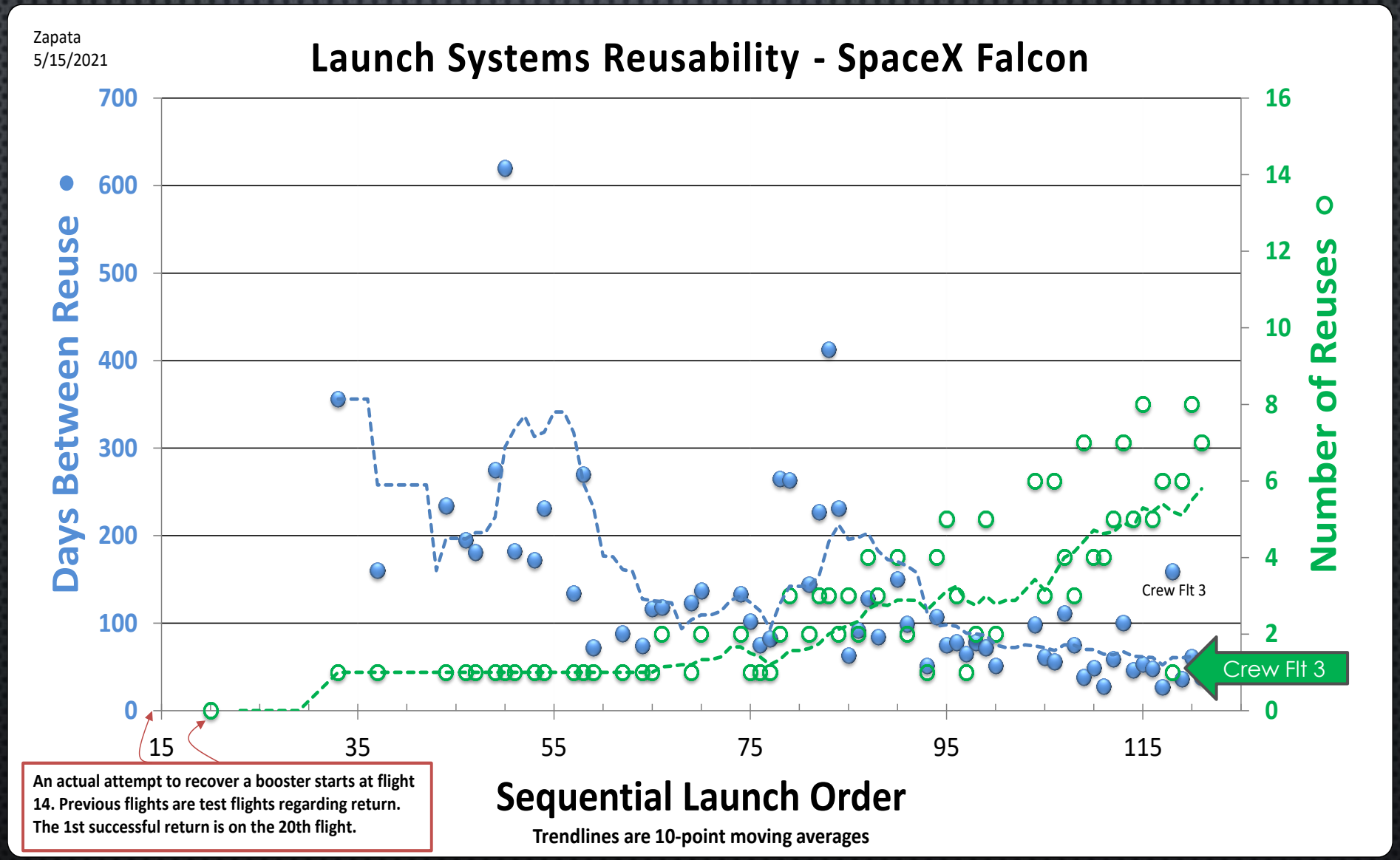
- The Falcon booster return success rate vs. attempts is:
  - 86% for drone ship landings
  - 96% for land landings
  - 88% overall
- Falcon Heavy 3-boosters are each counted here (points may overlap, i.e., 2 boosters on flight 76 each had the same turnaround days)



SUSTAINABILITY

CREW FLIGHT NUMBER OF REUSES = 1

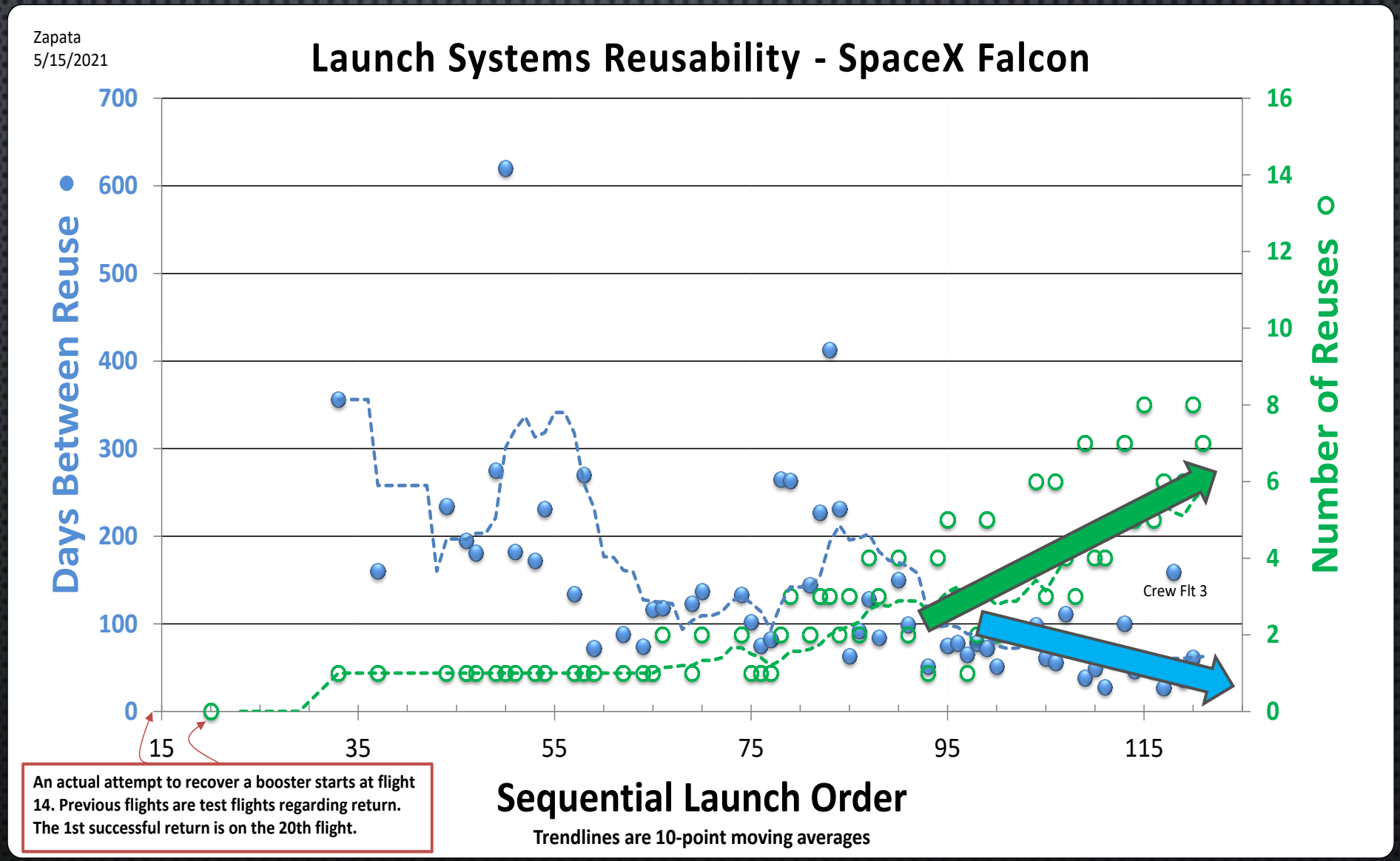
(PUSHES TRENDLINE DOWN)



SUSTAINABILITY

GOODNESS TRENDING UP

LANDING RELIABILITY TRENDING UP



DOD NSSL

- As of Dec. 2019 SAR
- **Note!** The NRO also contributes funds to the NSSL program. These additional $ are NOT included here.
  - NRO covers 25% of the fixed yearly payment to ULA.
  - This NRO amount is likely in the range of an additional $300M a year.
- For comparison on unit costs, also see GAO-18-360-SP, pp.128, a unit cost of **$342.54M** in 2018 dollars.
- **Note!** The apx. $1B a year to ULA apart from services for a launch continues, even though at times thought to be phased out by 2020. There is now Launch Vehicle Production Services (LVPS) and Launch Operations Services (LOPS).
- Pending – further documentation and traceability on the fixed amount to ULA not included when announcing launch contract awards (but awards to SpaceX appear to be total amounts.)

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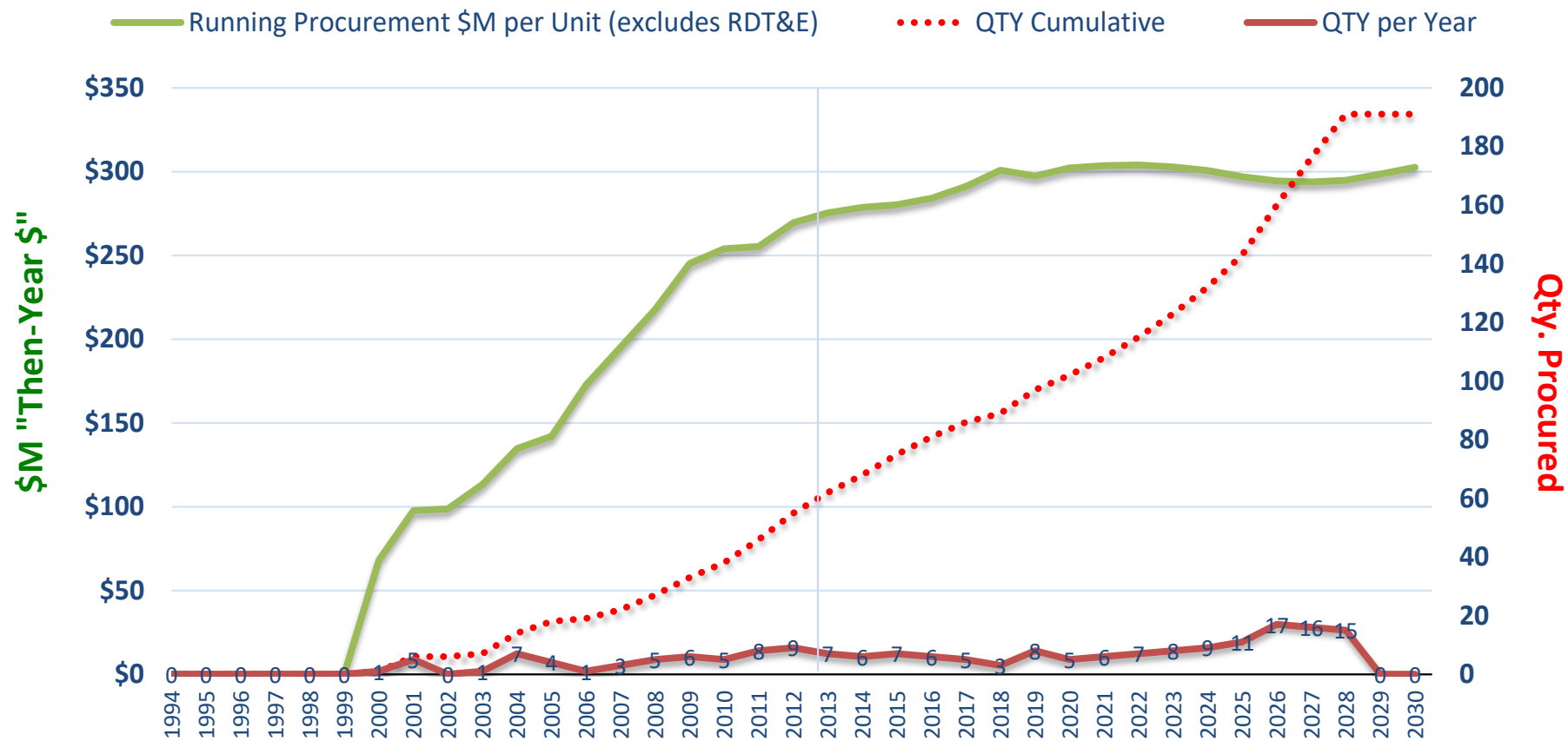
National Security Space Launch (was EELV)
Program Annual Funding vs. Quantity Procured



Data from Dec. 2019
Selected Acquisition Reports
Qty Procured/year are not Qty launched.

Dec. 2012 DoD opens EELV program to competition

SpaceX 2017=2, '18=1, '19=1, '20=2 to date
ULA 2017=5, '18=4, '19=4, '20=3 to date

DOD NSSL

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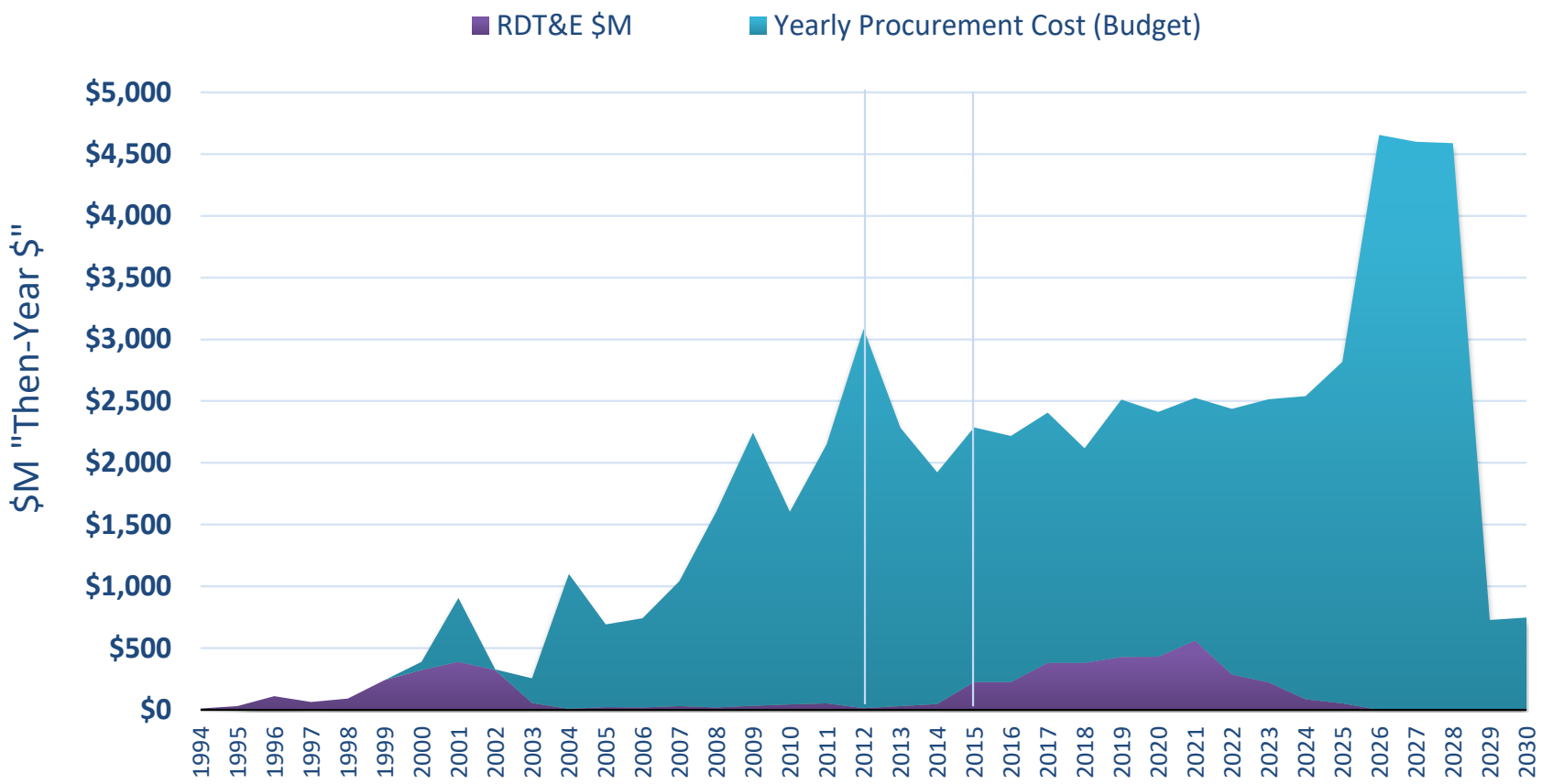
National Security Space Launch (was EELV) Program Annual Funding



Data from Dec. 2019
Selected Acquisition Reports

Dec. 2012 DoD opens EELV program to competition

SpaceX 2017=2, '18=1, '19=1, '20=2 to date
ULA 2017=5, '18=4, '19=4, '20=3 to date

Restart RDT&E: ATK, AR, SpaceX, Vulcan

"Appropriators in a report accompanying the bill point out what industry and government officials have been saying for years: ***that the development of commercial launch systems has substantially reduced the cost of launching satellites to orbit. The price of launches under the National Security Space Launch (NSSL) program, meanwhile, do not appear to be coming down.*** *The 2020 budget funded four launches for $1.2 billion. The 2019 budget funded $1.7 billion for five NSSL launches."*

Spacenews.com July 16, 2020

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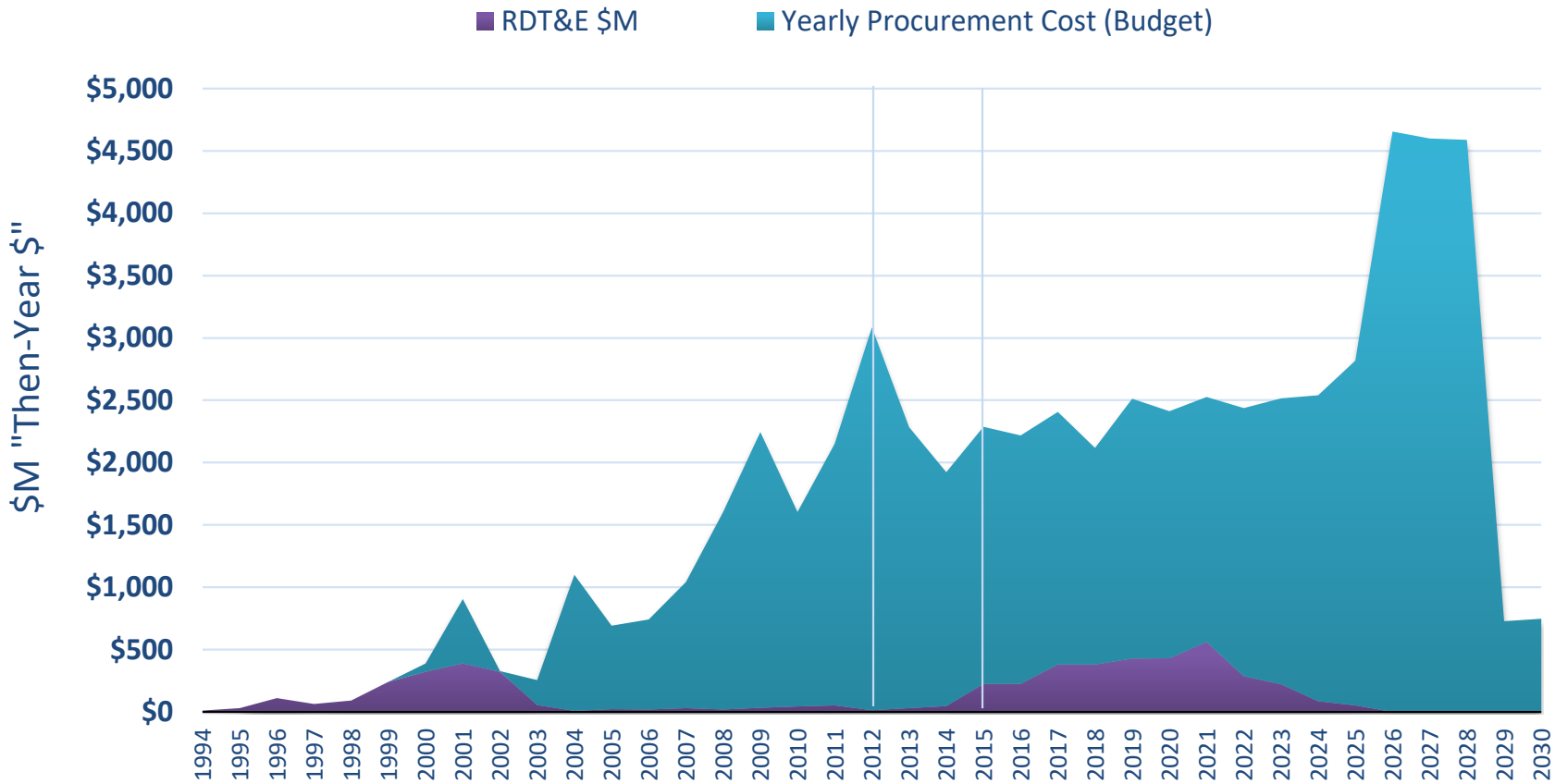
National Security Space Launch (was EELV) Program Annual Funding



Data from Dec. 2019
Selected Acquisition Reports

NASA SLS / ORION

- Prime contract data from govtribe.com reconciled with public budgets (exploration ground ops and typical/estimates for government management yield the "REMAINDER").
- Adds up to 100% of the NASA funds on the development that is now SLS, Orion and Ground Systems / Operation (KSC). See prior "NASA Budget" graph.
- **Note!** Does not include mission / flight operations (JSC). Pending distinguishing which of this is under Orion vs. other Human Spaceflight budget lines.
- Pending distinguishing funds, 2019 forward that start to count toward a recurring operational flight if counting a first flight as ending development.

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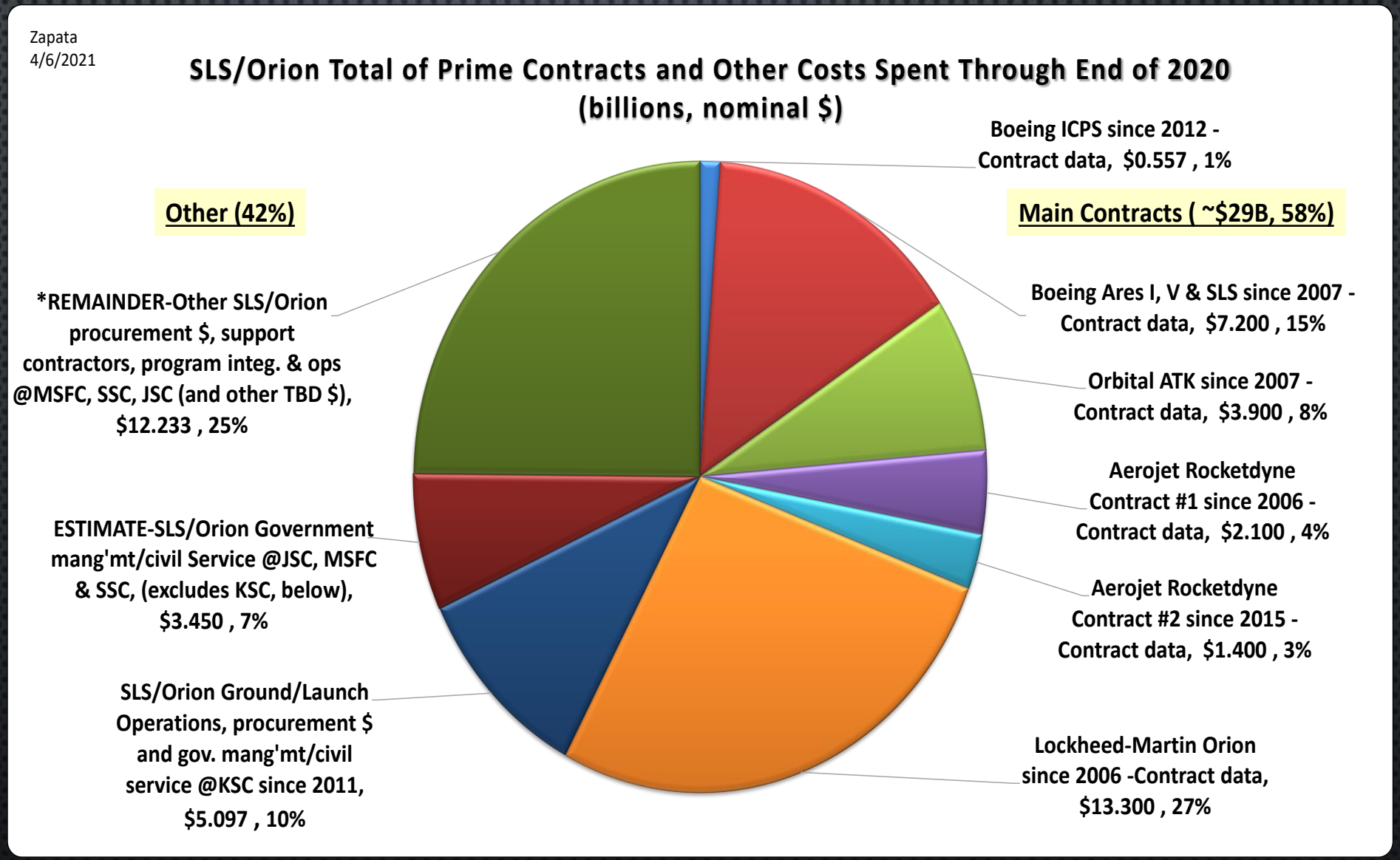

NASA SLS / ORION

42% OF COSTS NOT AS VISIBLE AS THE "PRIME" VERY PUBLIC CONTRACTS

"THE VAB EFFECT"

Also – ground ops always in, but *mission ops missing re. Space Flight Support (SFS)-see NASA Budget graph*

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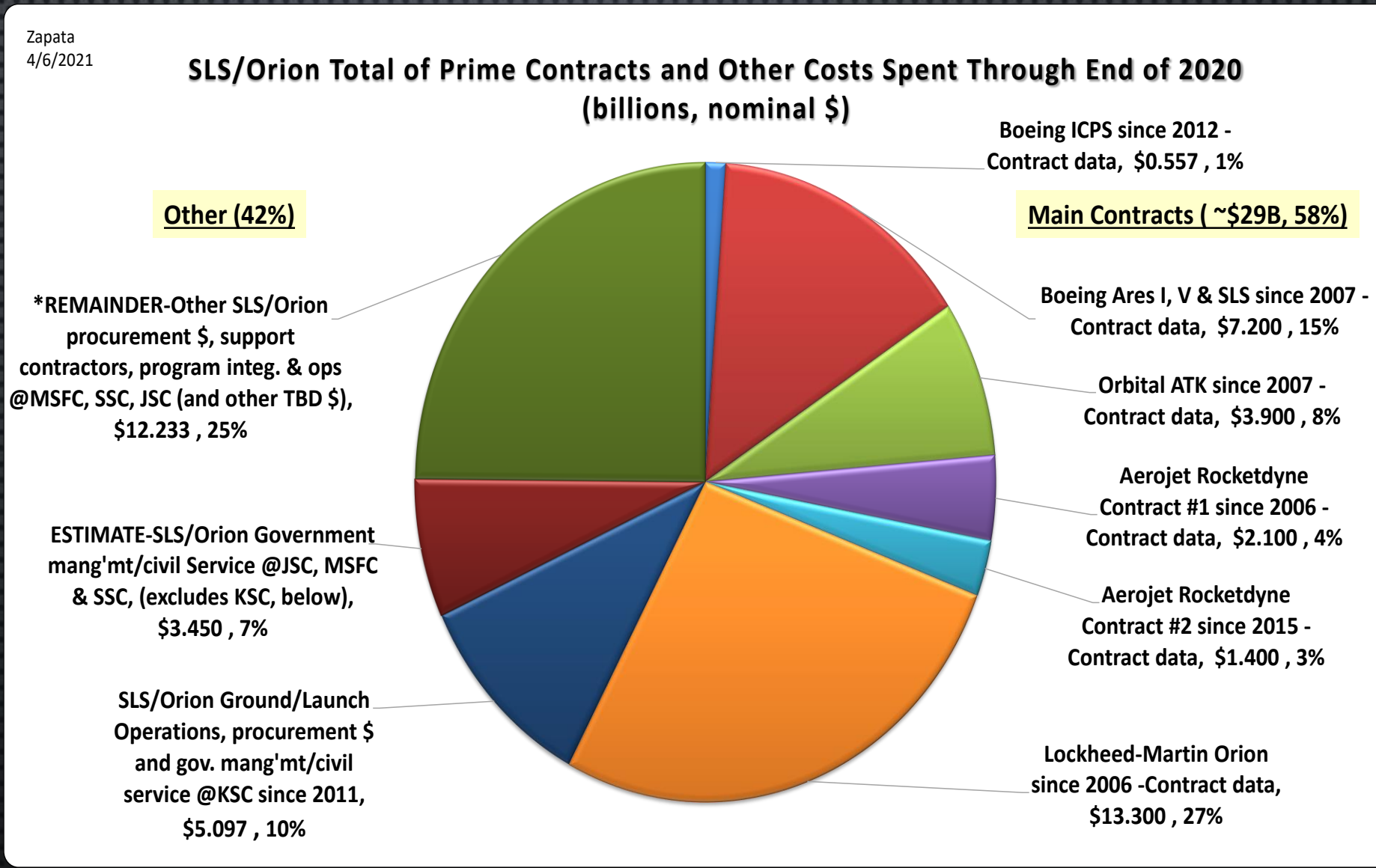
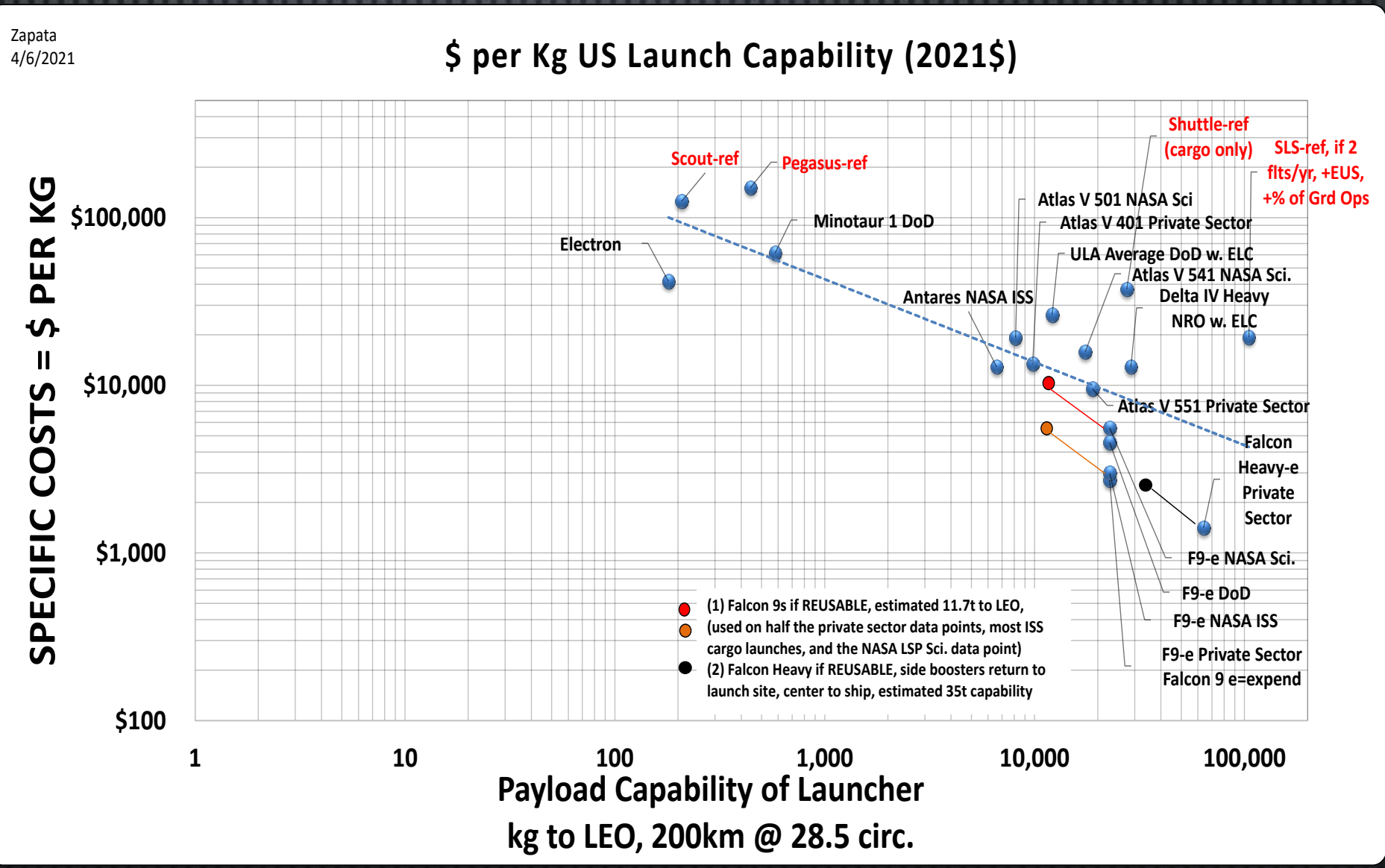


US LAUNCH PRICES AS $/KG OF PAYLOAD

- Assorted inconsistencies are introduced here in attempting to compile cost data that are not available in one program exactly as book kept or visible in another program. None of these inconsistencies if adjusted for would alter the basic picture significantly.



US LAUNCH PRICES AS $/KG OF PAYLOAD

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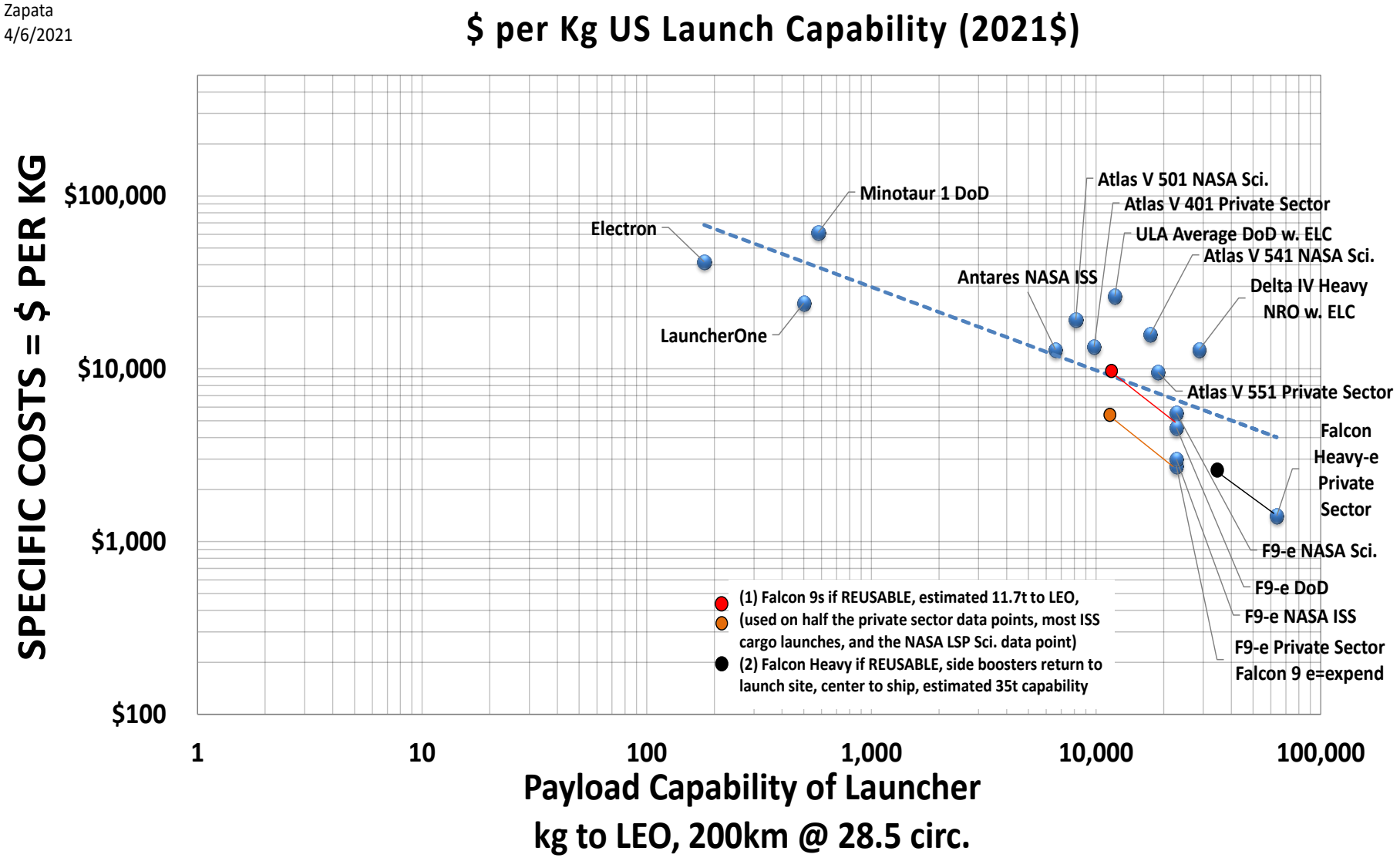


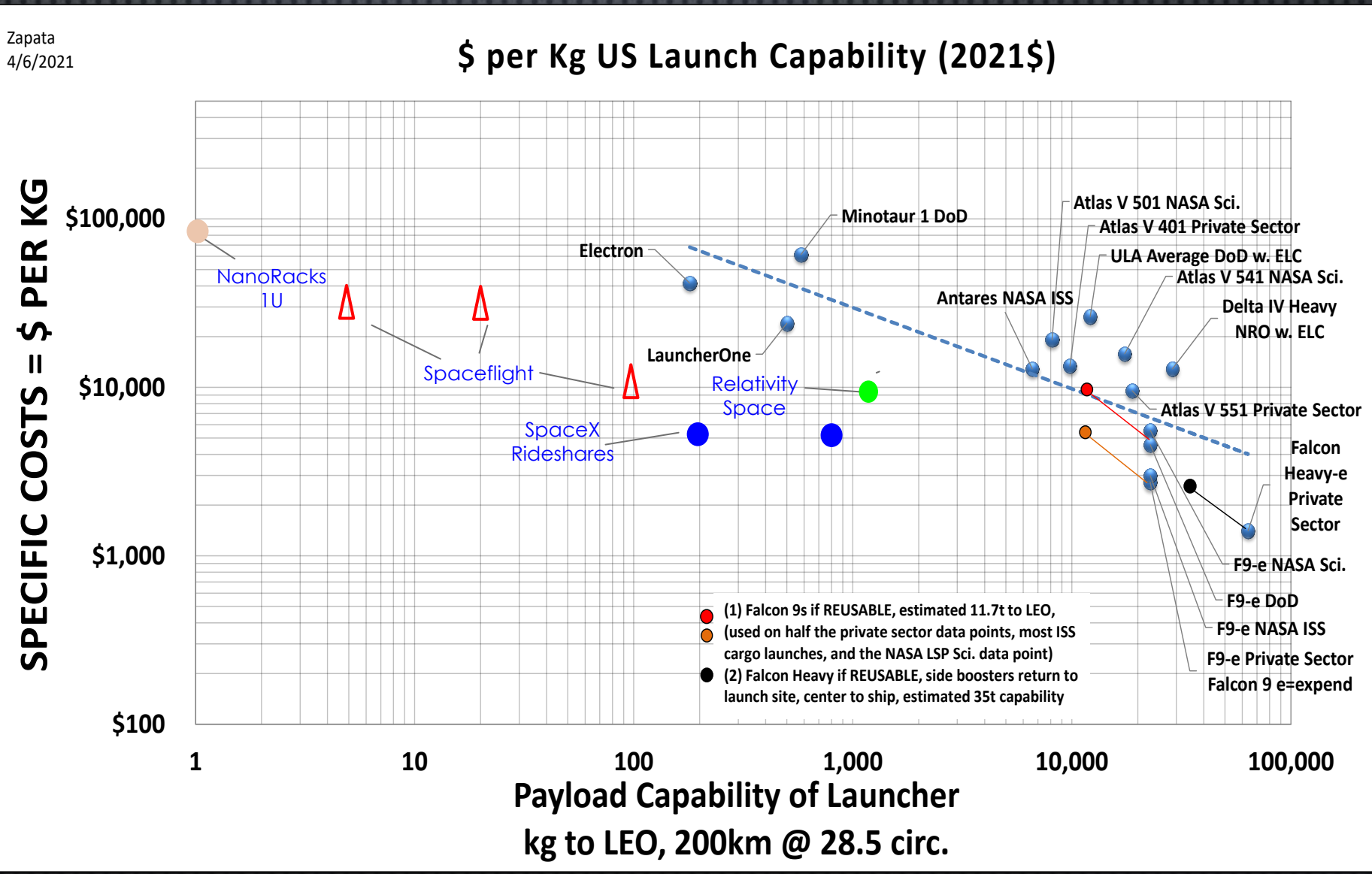
US LAUNCH PRICES AS $/KG OF PAYLOAD

Available

- Nanoracks as of 3/13/2018
- Spaceflight, examples as of 7/9/2020
- SpaceX Rideshare 200kg and 830kg LEO/SSO $1M and $4.15M as of 7/9/2020 link

Upcoming

- Relativity Space as of 11/3/2020 link



GLOBAL LAUNCH PRICES AS $/KG OF PAYLOAD

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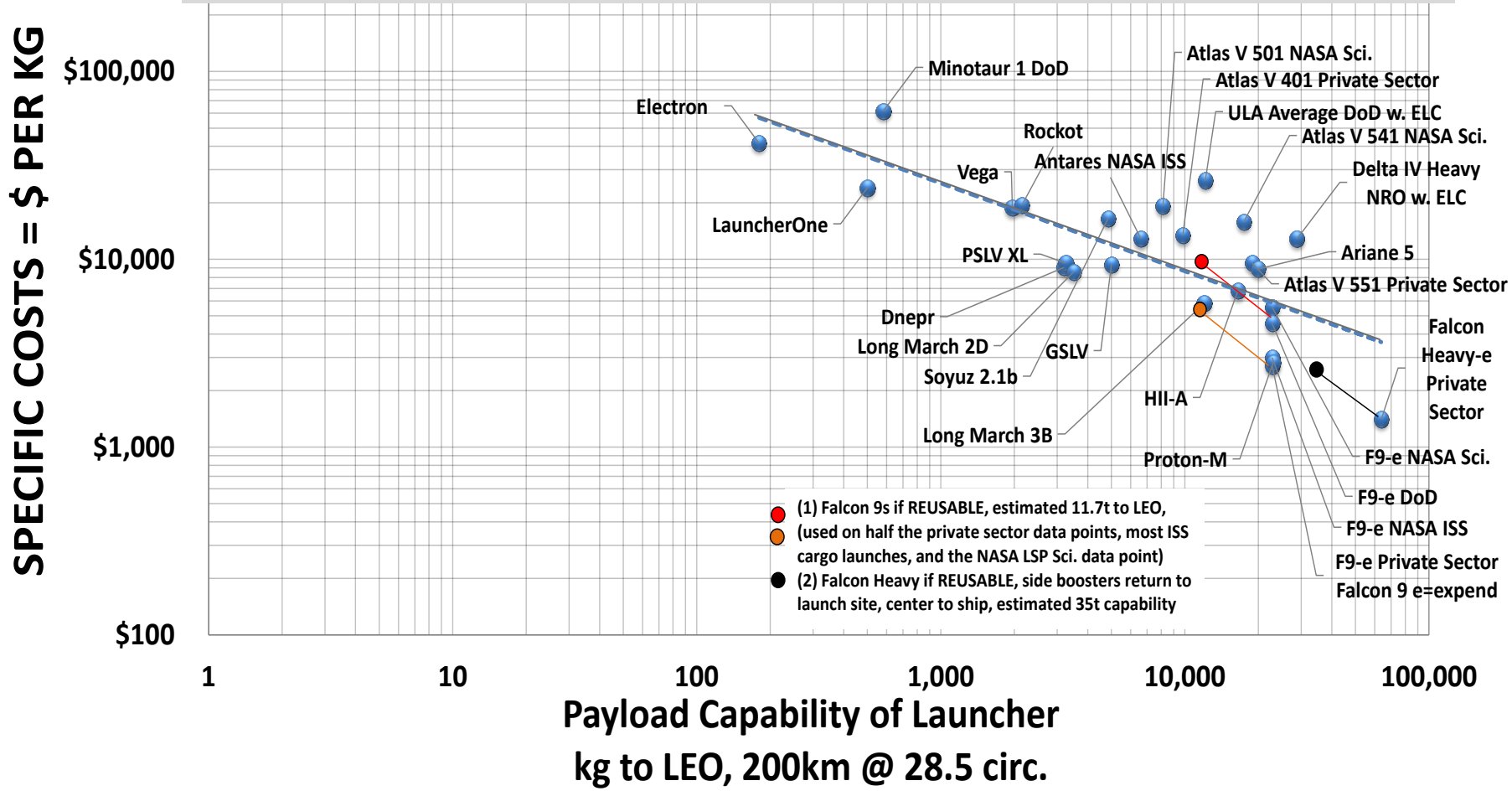
$ per Kg Global Launch Capability (2021$)

Non-US launcher data from the FAA, "The Annual Compendium of Commercial Space Transportation: 2018". Small launchers have slight variations from normalized LEO (200km, 28.5 circ.) capabilities of all data (e.g, LauncherOne 230km, 0 deg.)



GLOBAL LAUNCH PRICES AS $/KG OF PAYLOAD

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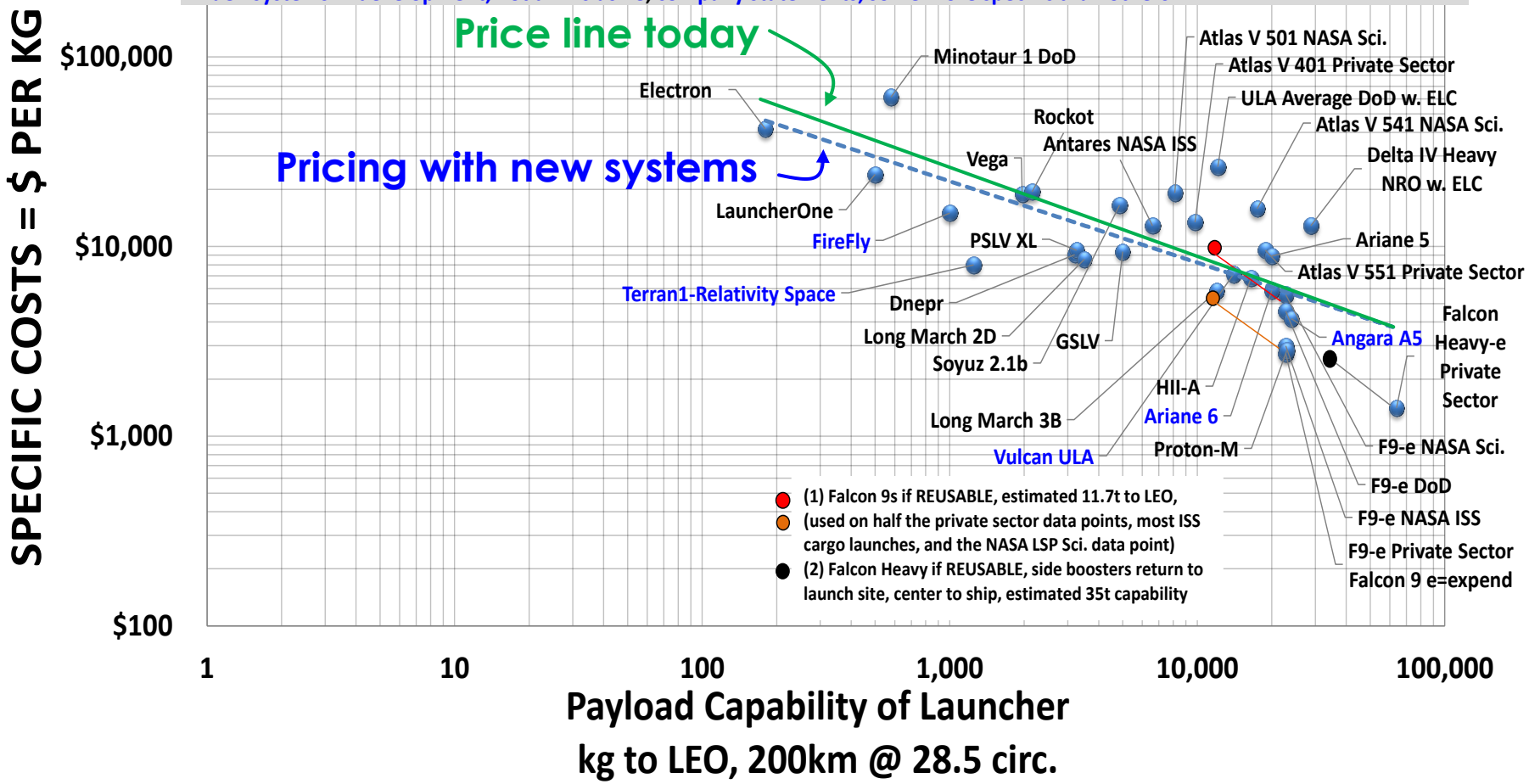
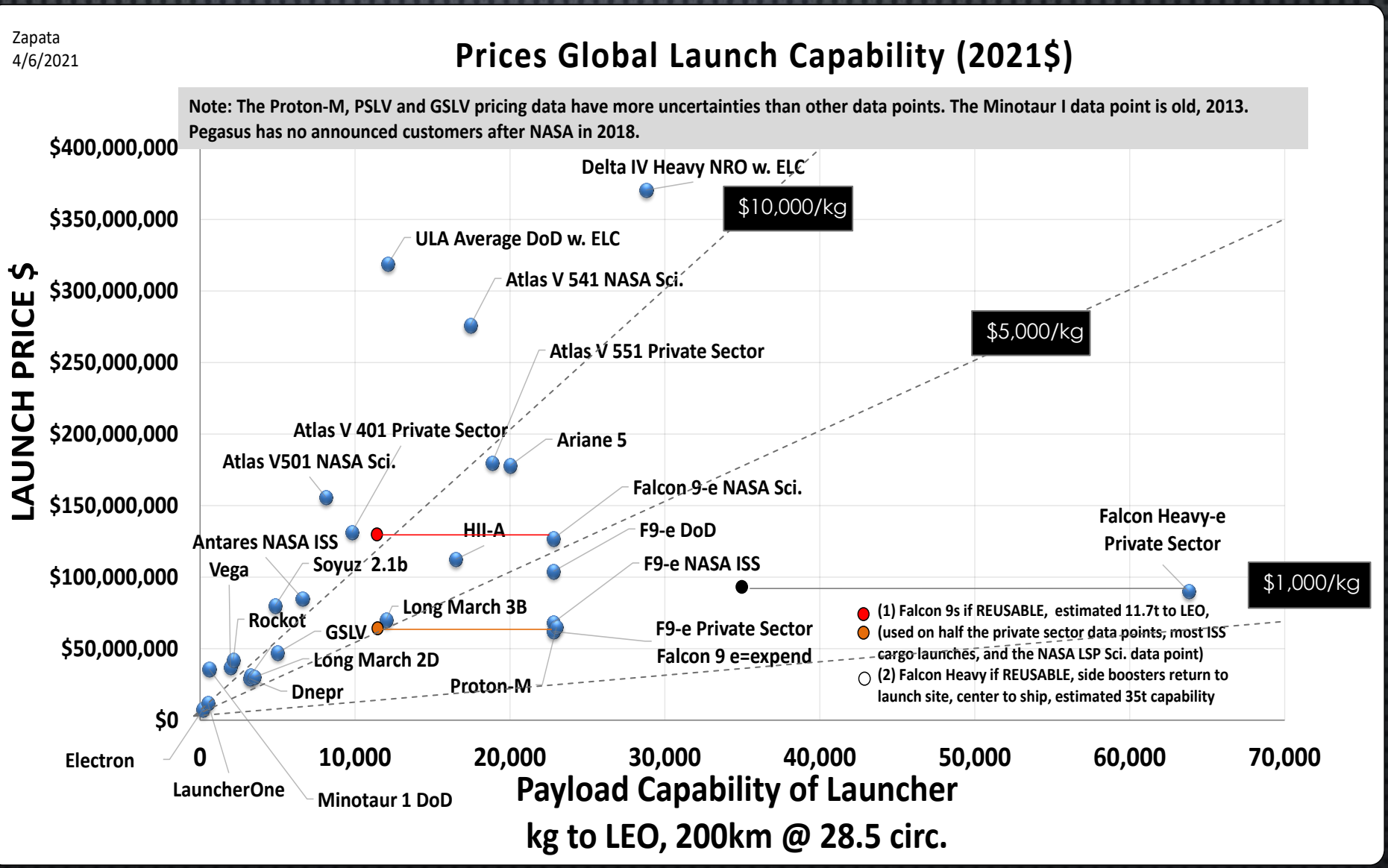
Non-US launcher data from the FAA, "The Annual Compendium of Commercial Space Transportation: 2018". Small launchers have slight variations from normalized LEO (200km, 28.5 circ.) capabilities of all data (e.g, LauncherOne 230km, 0 deg.)
Blue - systems in development, not all inclusive, company statements, some more specific than others.



GLOBAL LAUNCH PRICES vs. PAYLOAD CAPABILITY

Falcon 9 and Antares "NASA ISS" prices are derived, the portion of pricing for just the launcher in that use-case, excluding the actual required spacecraft, Dragon or Cygnus respectively. Total pricing is actually higher once Dragon and Cygnus are included – see https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170008895.pdf



SPACECRAFT

Spacecraft Development Costs

Costs = Procurement Price to NASA (includes Prime and non-Prime)

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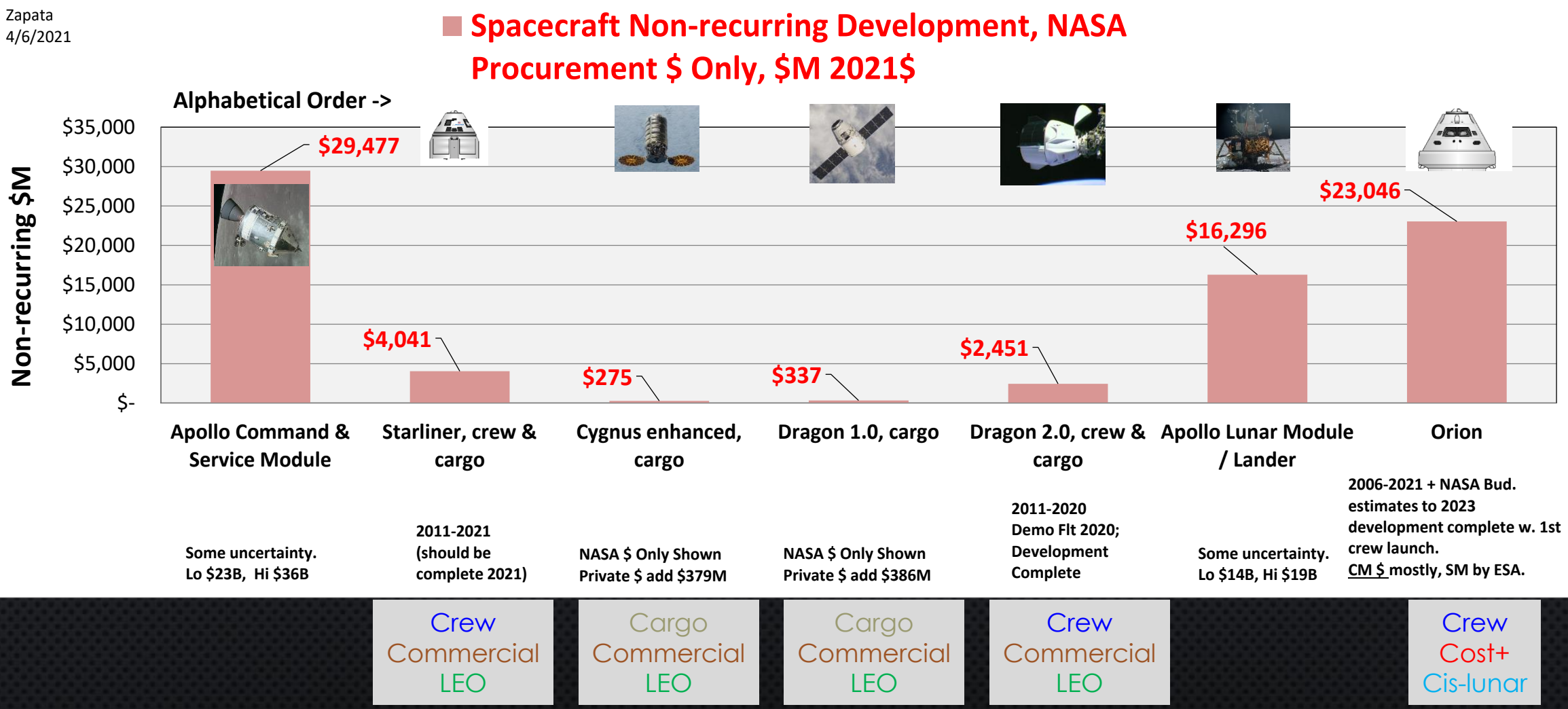

Spacecraft Per Unit Costs – $ Thru Cost Phase as Indicated

Costs = Procurement Price to NASA (includes Prime and non-Prime)

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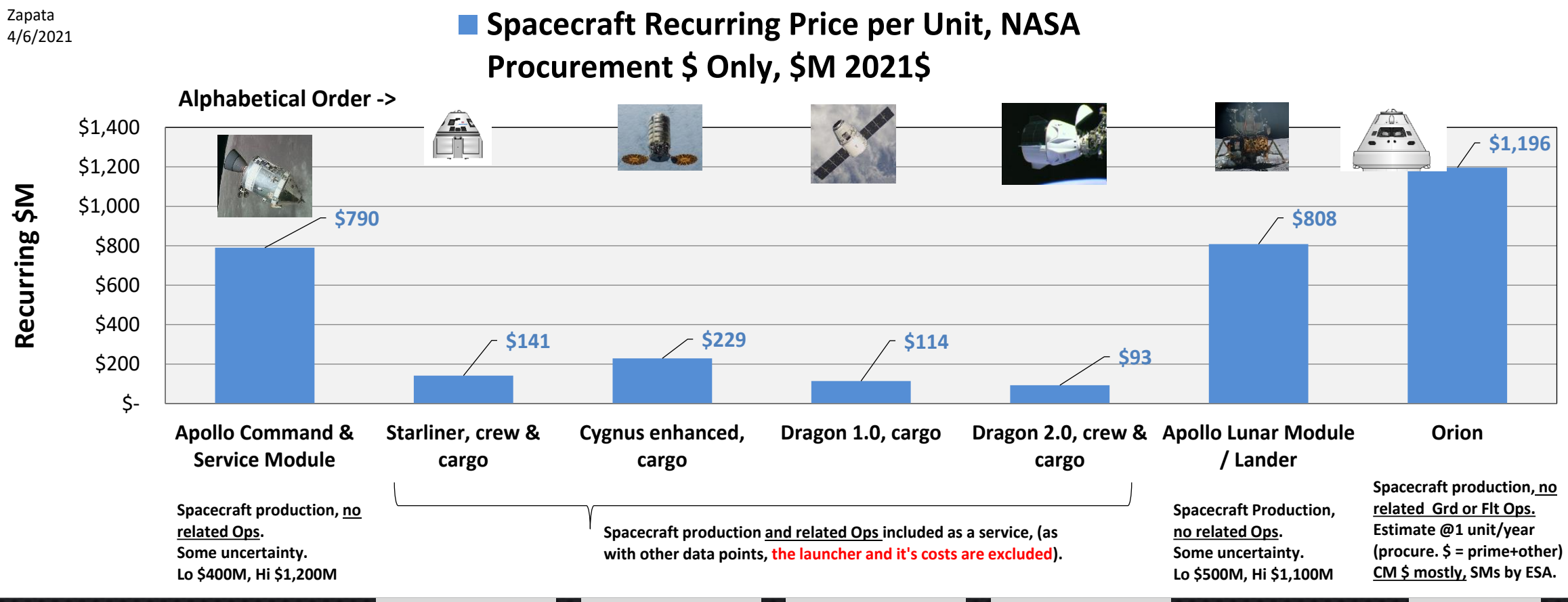

Crew Commercial	Cargo Commercial	Cargo Commercial	Crew Commercial		Crew Cost+
Manuf. $ Only	← Manuf. and Launch Ops Process $ →			Manuf. $ Only	Manuf. $ Only

EXCITING TIMES!

- Commercial LEO Stations and Commercial @ ISS
- Commercial Private – Inspiration4
- Cargo to the moon – CLPS – Commercial Lunar Payload services
- Human Lander System – partnership/commercial - Starship
- NASA is also exploring partnerships for spacesuit development
- New vision for human exploration of space – commercial, a coalition of partnerships, more missions, more science –

  "push human presence deeper into the solar system"
- *And much more to come…*

Much more data to come, to understand and context to add

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